

WHAT IS CLAIMED IS:

1. An apparatus for controlling the movement of a catheter-like tool having a distal end responsive to a magnetic field and configured to be inserted into the body of a patient, comprising:
  - a magnetic field source for generating a magnetic field outside the body;
  - a gimbal system to orient said magnetic field source with respect to the body;
  - a radar system to measure a location of said distal end;
  - a sensor system to measure positions of a plurality of fiduciary markers;
  - a user input device for inputting commands to move said distal end;
  - a system controller for controlling said magnetic field source in response to inputs from said user input device, said radar system, and said sensors;
2. The apparatus of Claim 1, said system controller comprising a closed-loop feedback servo system.
3. The apparatus of Claim 1, said radar system comprising an impulse radar.
4. The apparatus of Claim 1, said distal end comprising one or more magnets.
5. The apparatus of Claim 1, where said system controller calculates a position error and controls said magnetic field source to move said distal end in a direction to reduce said position error.
6. The apparatus of Claim 1, where said system controller integrates a position data of said distal end with a set of fiduciary markers.
7. The apparatus of Claim 1, where said system controller synchronizes a location of said distal end with a fluoroscopic image.
8. The apparatus of Claim 1, further comprising an operator interface unit.

9. The apparatus of Claim 1, wherein said system controller compensates for a dynamic position of an organ, thereby offsetting a response of said distal end to said magnetic field such that said distal end moves in substantial unison with said organ.

10. The apparatus of Claim 1, wherein a correction input is generated by an auxiliary device that provides correction data concerning a dynamic position of an organ, and wherein said correction data are combined with measurement data from said radar system to offset a response of said control system so that said distal end moves substantially in unison with said organ.

11. The apparatus of Claim 10, wherein said auxiliary device comprises at least one of an X-ray device, an ultrasound device, and a radar device.

12. The apparatus of Claim 1, wherein said user input device comprises a virtual tip control device to allow user control inputs.

13. The apparatus of Claim 1, further comprising: a virtual tip with force feedback.

14. The apparatus of Claim 1, further comprising:  
an X-axis controller and amplifier;  
a Y-axis controller and amplifier; and  
a Z-axis controller and amplifier.

15. The apparatus of Claim 1, said sensor system comprising a 6-DOF sensor.

16. The apparatus of Claim 1, wherein said radar device comprises a phased array.

17. The apparatus of Claim 1, wherein said system controller coordinates operation of an X-axis Controller, a Y-axis Controller, and a Z-axis Controller, and wherein said user input device comprises a virtual tip.

18. The apparatus of Claim 17, wherein said Virtual Tip provides tactile feedback to an operator.

19. The apparatus of Claim 17, wherein said Virtual Tip provides tactile feedback to an operator according to a position error between an actual position of said distal end and a desired position of said distal end.

20. The apparatus of Claim 17, wherein said system controller causes said distal end to follow movements of said Virtual Tip.

21. The apparatus of Claim 1, wherein said radar system is configured to measure second harmonics produced by said distal end.

22. The apparatus of Claim 1, further comprising a virtual tip controller, wherein said Virtual Tip Controller outputs a tactile feedback response control to a Virtual Tip.

23. The apparatus of Claim 1, wherein said system controller is configured to calculate a position error of said distal end of the catheter tip using at least in part data from said radar device and the 6-DOF sensor in order to control said magnetic field source to reduce said position error.

24. The apparatus of Claim 1, wherein said system controller initiates a tactile feedback response by providing feedback data to said user input device.

25. A method for controlling movement of a tool having a distal end to be inserted in a body, comprising;

applying a force to said distal end by generating an external magnetic field; regulating said force to move said distal end in a desired direction; and locating said distal end by radar.

26. The method of Claim 25, further comprising changing a visual representation of said distal end in substantially real time as said distal end moves through the body.

27. The method of Claim 25, further comprising controlling one or more electromagnets to produce said external magnetic field.

28. The method of Claim 25, further comprising locating a plurality of fiduciary markers and synchronizing said markers with positions on a real-time image of at least a portion of the body.

29. The method of Claim 25, further comprising determining a current position of said distal end in comparison to a desired location.

30. The method of Claim 25, wherein determining said current position of said tool distal end comprises:

inputting a dynamic cardio-position via said controller; and calculating said current position as a function of said cardio-position.

31. The method of Claim 25, further comprising computing a position error of said distal end.

32. The method of Claim 31, further comprising altering at least one of a duty cycle and a polarity of modulation inputs to at least one of said X-axis controller, said Y-axis controller, and said Z-axis controller when said position error is greater than a specified minimum value.

33. The method of Claim 31, further comprising producing a tactile feedback if said position error exceeds a predetermined amount along at least one axis.

34. The method of Claim 31, wherein said system controller causes said tool distal end to move so that its position corresponds to position data from a Virtual Tip.

35. An apparatus for controlling movement of a tool having a distal end to be inserted in a body, comprising;

a magnetic field source configured in a cluster-like arrangement on a C-Arm forming a magnetic circuit and generating a magnetic field;

a tool having a distal end responsive to said magnetic field;

one or more piezoelectric rings disposed about said distal end; and

a system controller for regulating said magnetic field to provide a position and command input to control said tool distal end position; and

a radar system for measuring a position of said distal end.

36. The apparatus of Claim 35, further comprising a closed servo loop system that receives said position and command input from said system controller, to regulate said magnetic force.

37. The apparatus of Claim 35, further comprising a radar system to locate said distal end.

38. The apparatus of Claim 35, wherein said system controller is configured to calculate respective torque and associated current for said magnetic source to configure said magnetic field to move said distal end to a desired location.

39. The apparatus of Claim 36, wherein said system controller provides a closed servo loop circuit that corrects for movement of an organ in the body such that said distal end moves substantially unison with said organ.

40. The apparatus of Claim 39, wherein data about movement of the organ is generated by an auxiliary device that provides dynamic data concerning said movement, and wherein when said dynamic data are combined with measured positions of a plurality of fiduciary markers that define a stereotactic frame.

41. The apparatus of Claim 40, wherein said auxiliary device comprises at least one of: a fluoroscopic imaging system, and ultrasonic imaging system, or a radar imaging system.

42. The apparatus of Claim 35, further comprising a Virtual Tip, wherein movement of at least a portion of said Virtual Tip causes said system controller to control said magnetic field source to move said distal end correspondingly.

43. The apparatus of Claim 35, further comprising a mechanical system for moving portions of said magnetic field source to reduce a current needed to produce a desired magnetic field strength.

44. The apparatus of claim 43, wherein said system controller uses at least position data from said radar system and fiduciary marker position data from a 6-DOF sensor to compute a position of said distal end with respect to a stereotactic frame.